Riemann Track Finder For MVD In PANDA experiment

- Motivation
- Main idea of the Riemann Track Finder
- Cut parameters
- Using Riemann track finder for MVD
- Using Riemann track finder for MVD + TPC
- Summary

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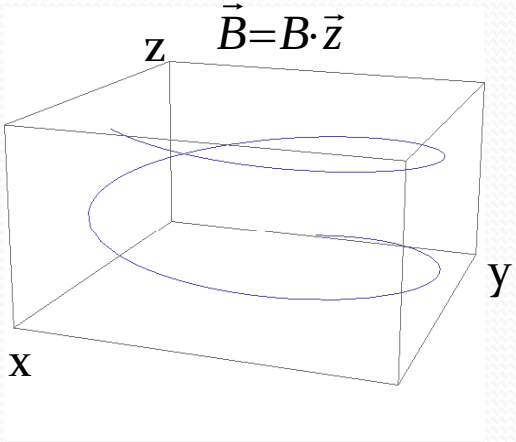
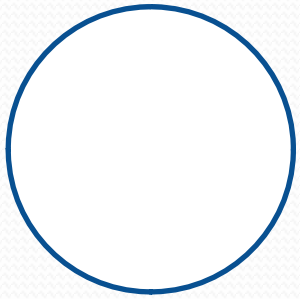
Motivation

- The main task is to find tracks with:
  - Highest **efficiency** for a large momentum range
  - Highest **speed**
  - **Low** number of "**ghost**" tracks
- After this it is possible to use found tracks as an input for the Kalman filter.

Main idea of the Riemann track finder

- In sufficiently homogeneous magnetic fields the track model can be assumed to be a perfect helix
- The projection of a helix on a XY-plane is a circle, so the first step is a circle fit, but direct circle fitting is non-linear and slow.
- The central idea of the Riemann circle fit is a mapping of the observations, which are supposed to lie in the XY-plane, on a second-order surface in space – in my case on the circular paraboloid $w = x^2 + y^2$





Equation of circle: $(x - x_0)^2 + (y - y_0)^2 = R_0^2$ ⟶

$$x^2 - 2 \cdot x \cdot x_0 + x_0^2 + y^2 - 2 \cdot y \cdot y_0 + y_0^2 - R_0^2 = 0 \longrightarrow$$

$$w = x^2 + y^2 \longrightarrow$$

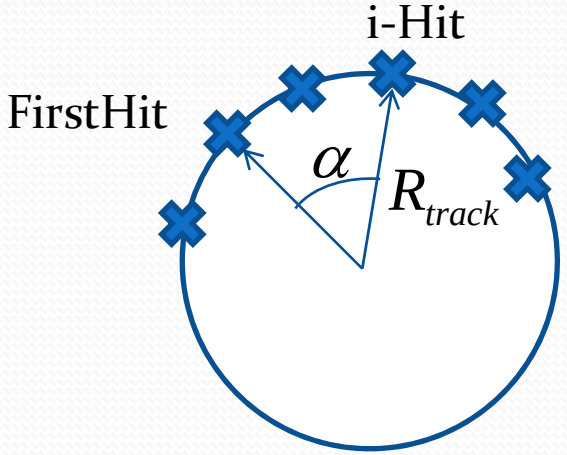
$$w - 2 \cdot x_0 \cdot x - 2 \cdot y_0 \cdot y + x_0^2 + y_0^2 - R_0^2 = 0$$

This is a plane equation in XYW-space(Riemann space)

The task of circle fit in XY-plane is transformed into the task of a plane fit in XYW-space.

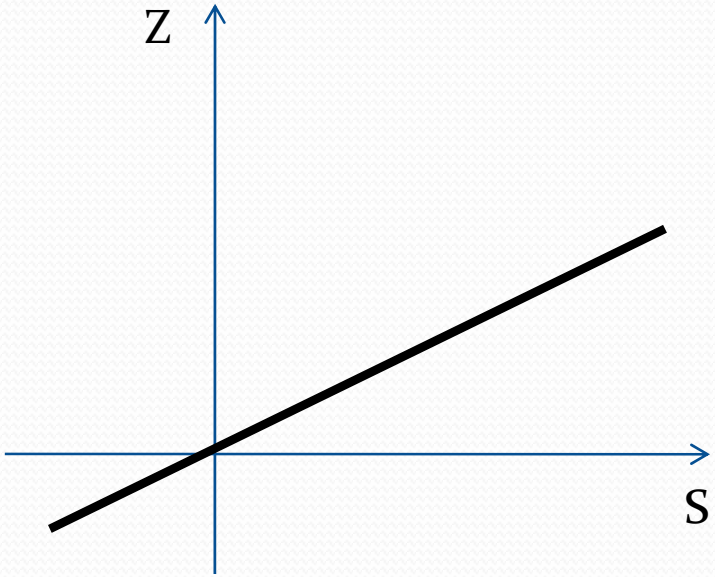
The second step of the track fit is a SZ-fit:

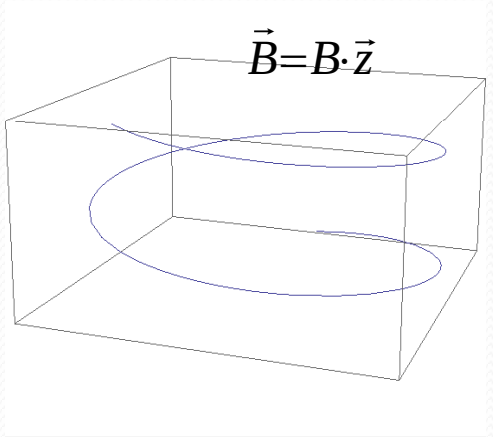
$S_i = \alpha \cdot R_{track}$ – the length of arc FirstHit - i-Hit.



Zi – z-coordinate of i-Hit.

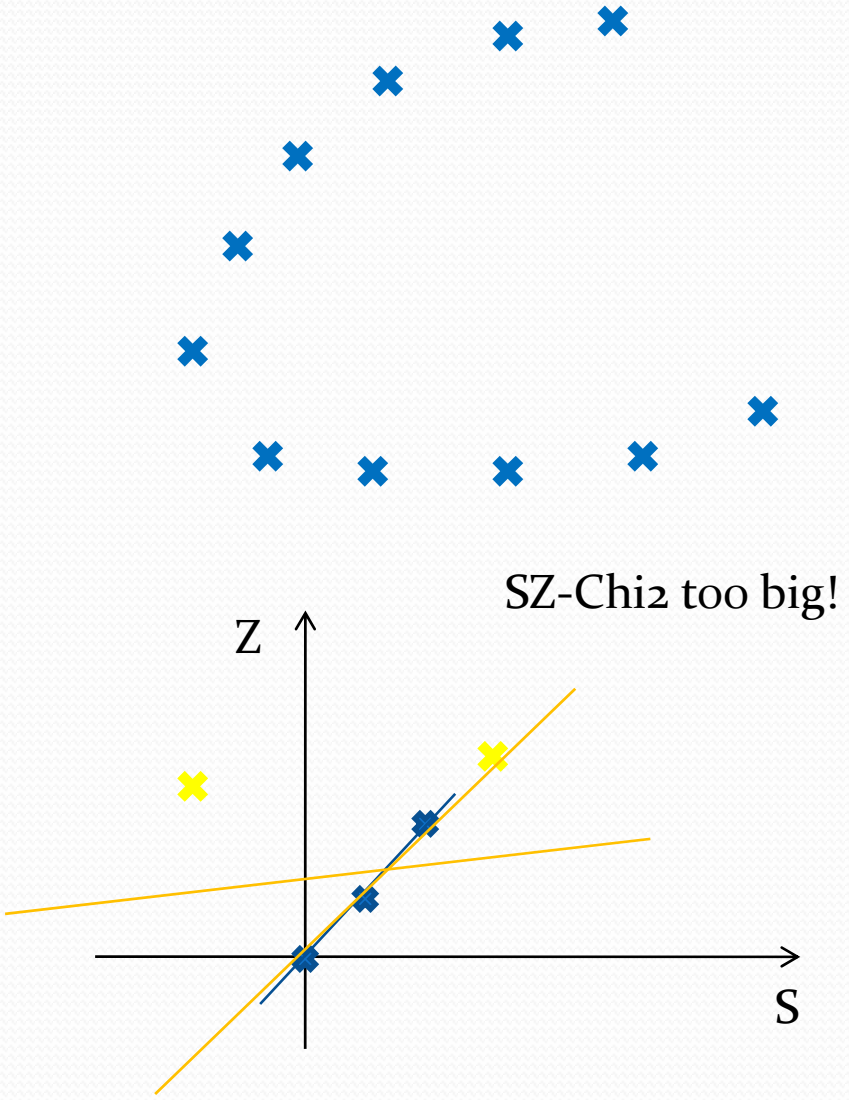
For the perfect helix track:





The main finding steps:

1. Get 3 random hits and fit them by the Riemann plane – we always can do it.
2. Do SZ-fit and check SZline-Chi2 of the SZ-line fitting. If SZline-Chi2 is less then some cut parameter we can use this 3 hits as a base seed for the Riemann plane.
3. Then we get the fourth hit and calculate the distance to the Riemann plane and Chi2 of SZ-fit. If the distance to the Riemann plane and SZline-Chi2 are less then some cut parameters we add this hit to the track and do refit of the Riemann plane.
4. Do point 3 for all other hits.



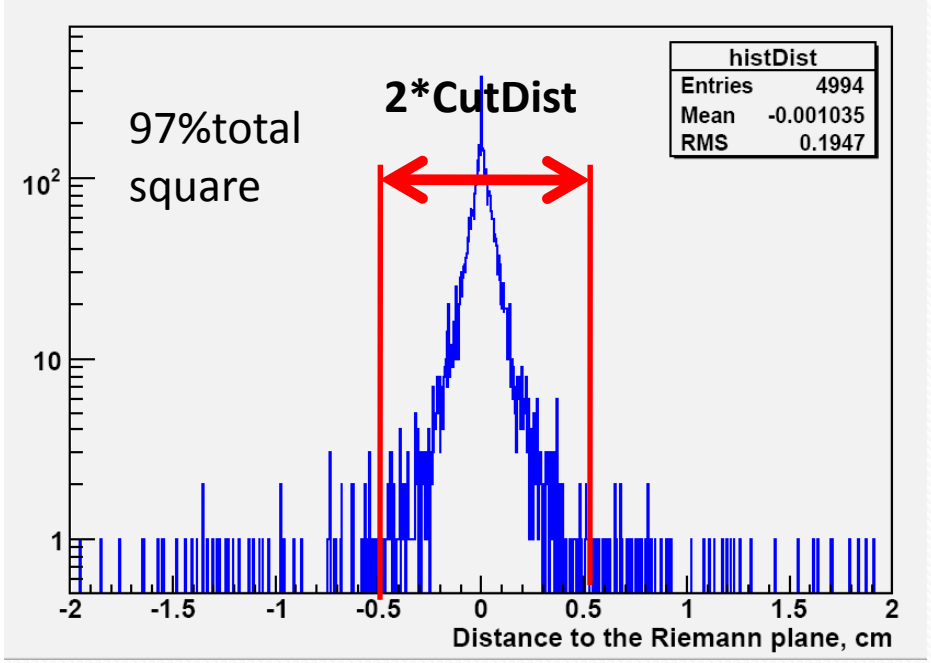
Cut parameters

There are two cut parameters :

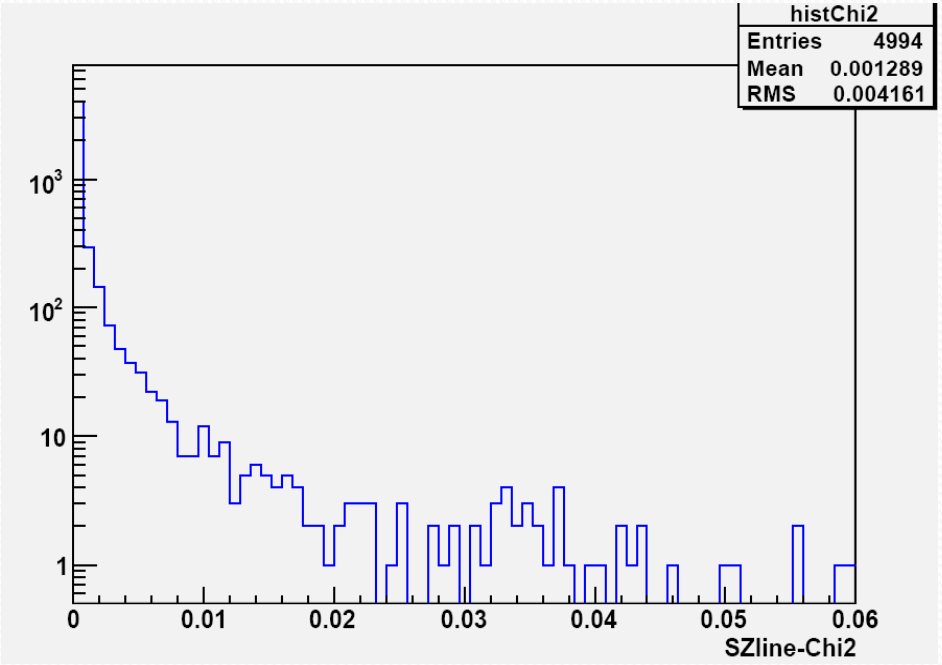
- Cut distance to the Riemann plane
- Cut Chi2 of SZ-line fitting.

We can get **3** random hits in the track, do refit and for all hits in this track calculate distance to the Riemann plane and SZline-Chi2.
Then draw histograms of this values.

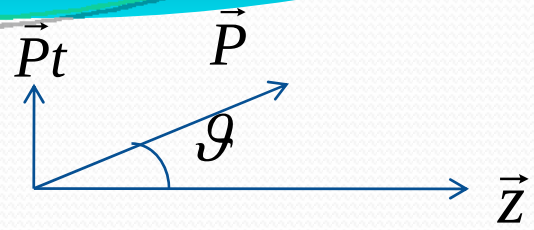
Distance to the Riemann plane:

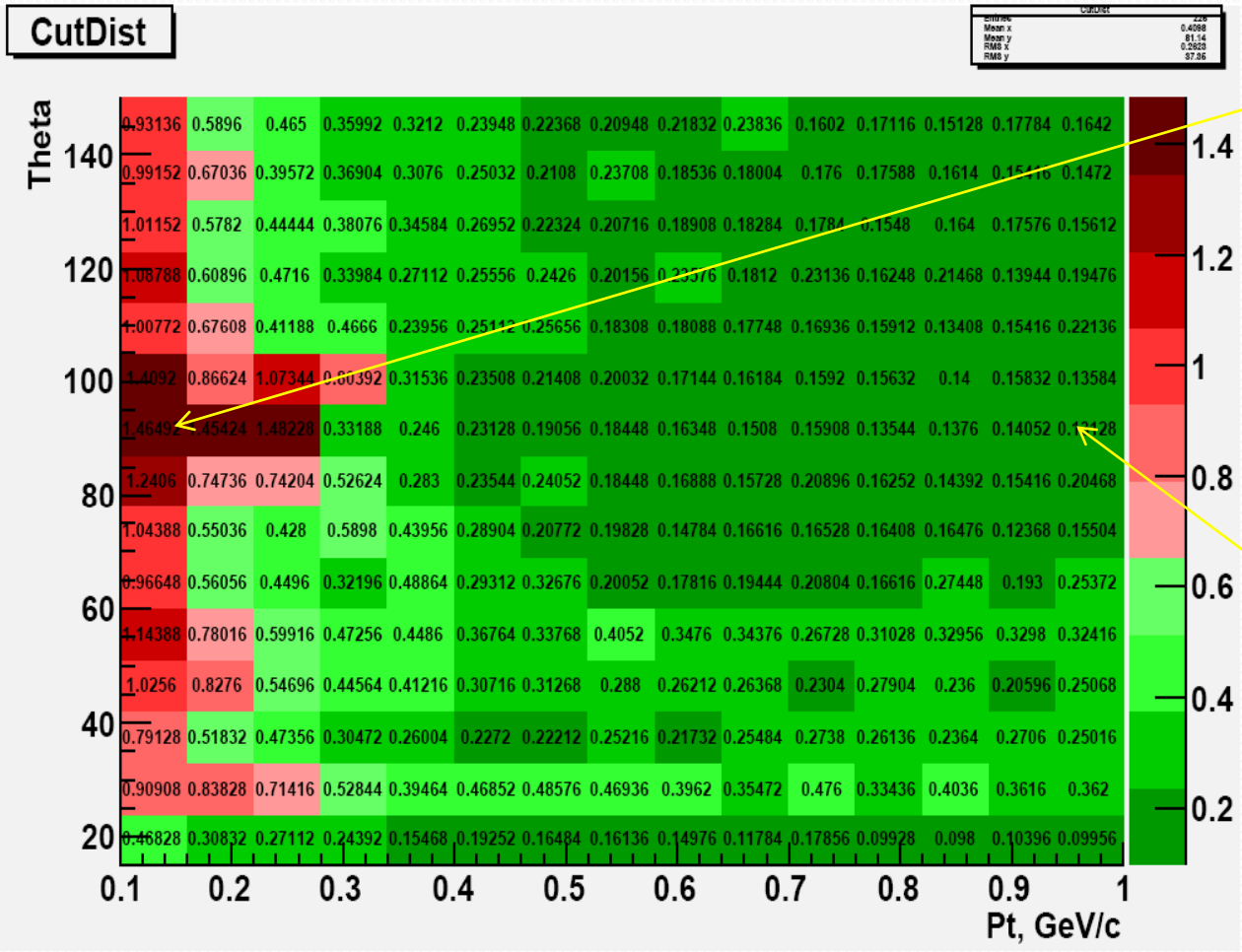


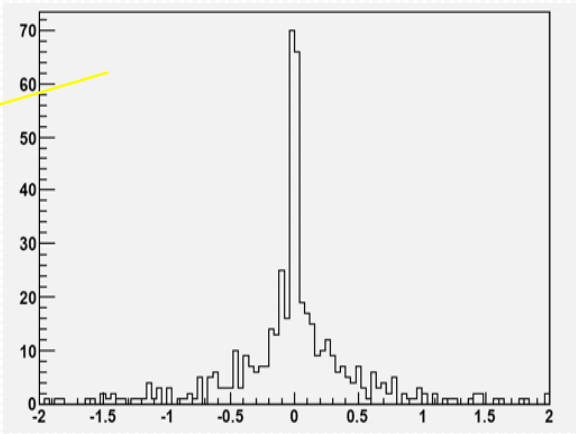
SZ-line Chi2:

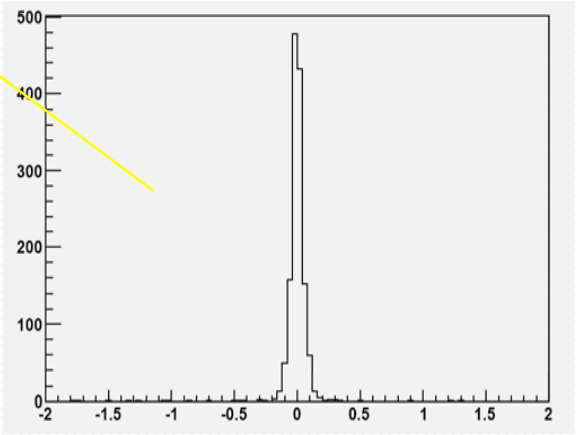


Calculated cut distances (**cm**) from **Pt** and **θ**
(Pt=P*Sin(θ) , P momentum of the particle):

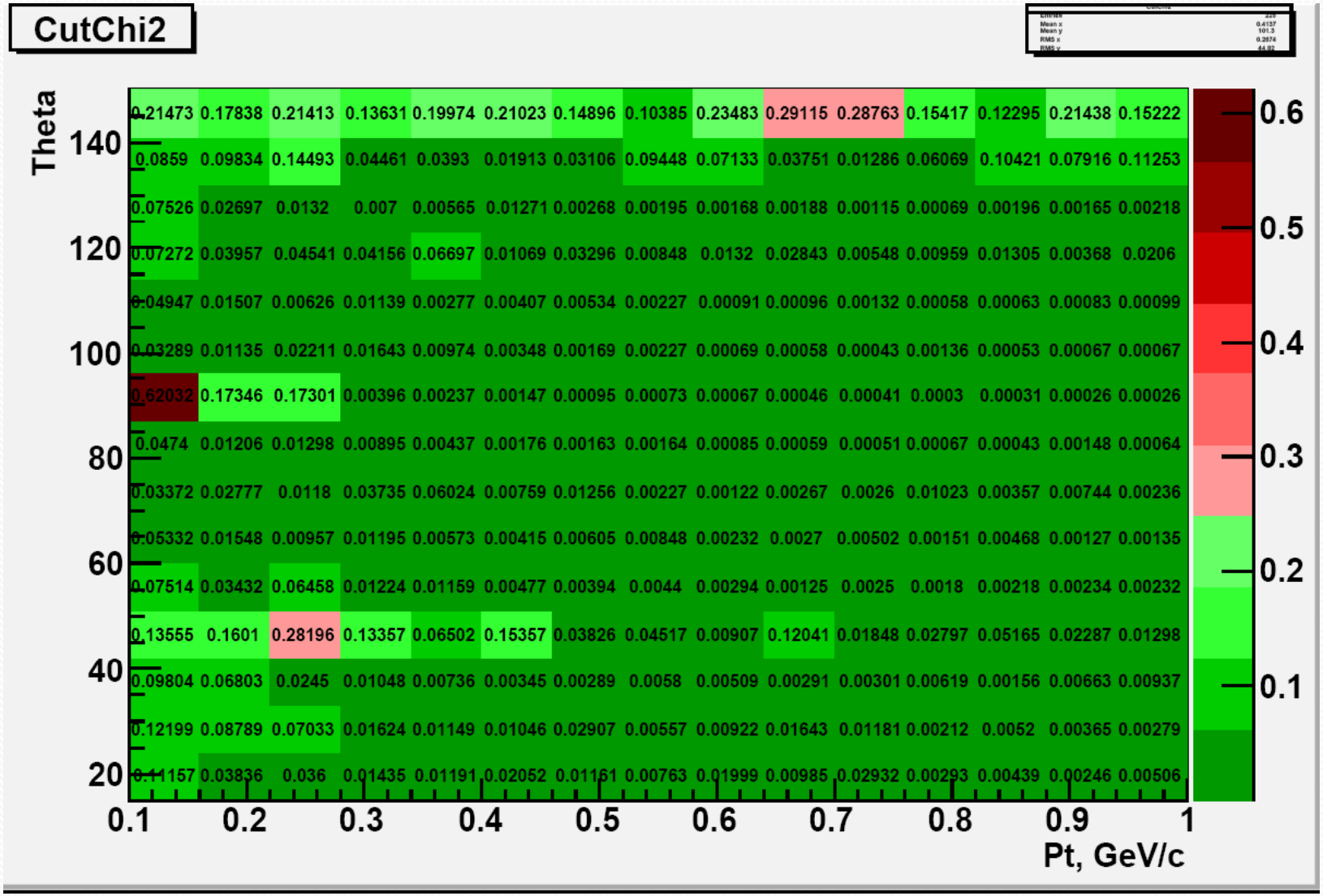




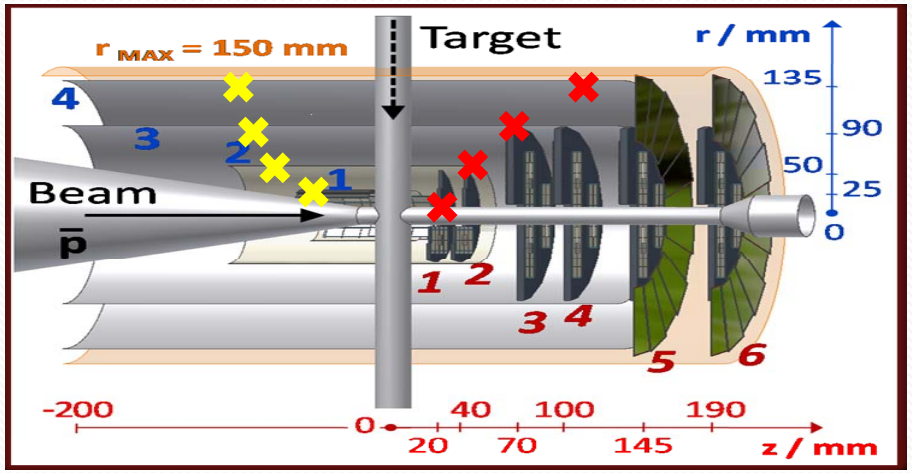




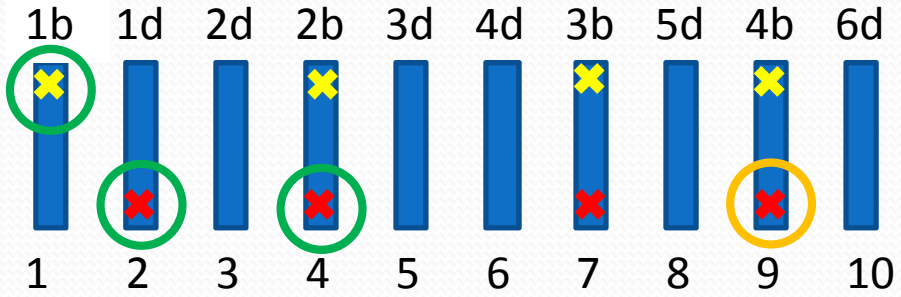
Calculated cut SZline-Chi2 from Pt and θ (Pt=P*Sin(θ) , P momentum of the particle):



Using the Riemann track finder for MVD in PANDA



b- barrel; d - disk



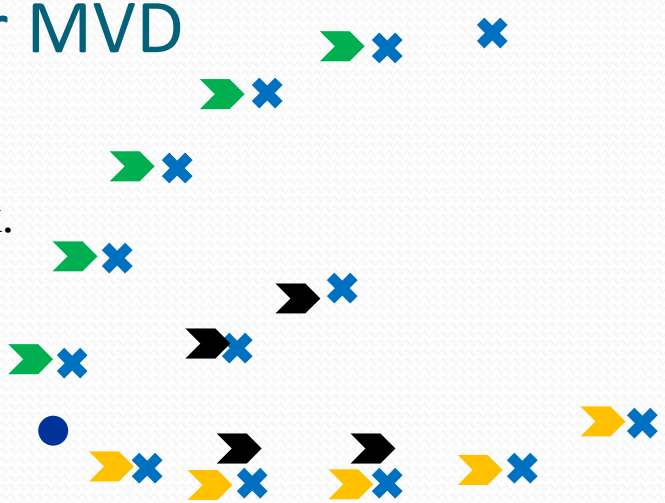
- MVD hits lie in the detector layers – barrels and disks.
- There are no hits from the same track in the same layer

Steps of finding:

1. Get all possible combinations of 3 hits going through all layers in order of increasing layer's number (this 3 hits have to lie in different layers), do refit of planes and check them using cut parameters.
2. Get base seed Riemann plane(if already found tracks don't include this 3 hits) and check all hits from the layers that have higher layer's number than the last hit in the base track. If checking is ok, add hit to the track and do refit.

Finding efficiency for MVD

True Found track – has at least **4** identical hits with Reco track and all of this hits belong to the Reco track.
"**Ghost**" **tracks**– all other found tracks.



Total finding efficiency = $\frac{\text{NumberOfTrueFoundTracks}}{\text{NumberOfMCTracks}}$

TFE=2/3=66%

Finding efficiency = $\frac{\text{NumberOfTrueFoundTracks}}{\text{NumberOfRecoTracksWhichHaveAtLeast4Hits}}$

Blue – RECO-hits

Green ,Yellow and **Black** – Hits of found tracks

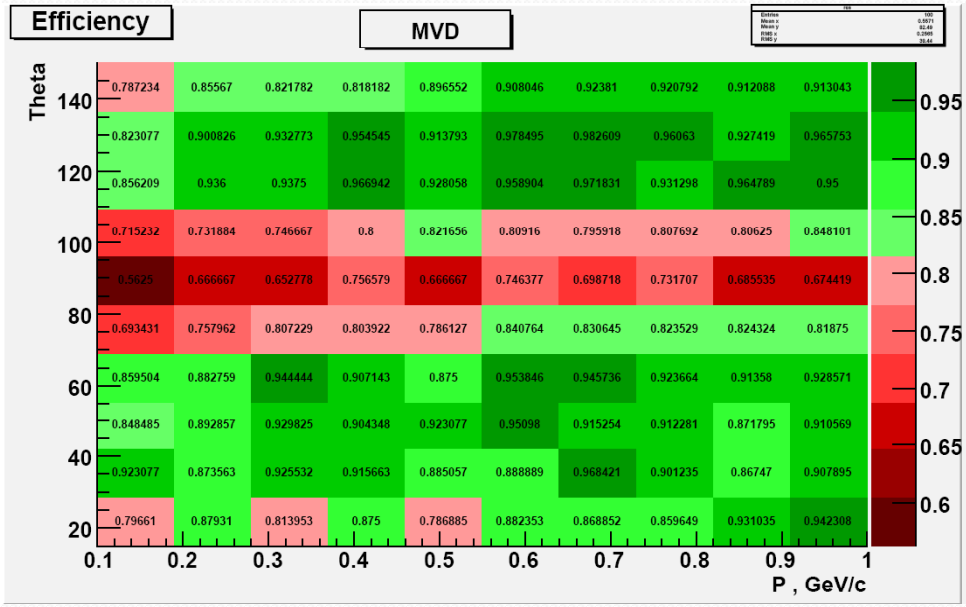
FE=2/2=100%

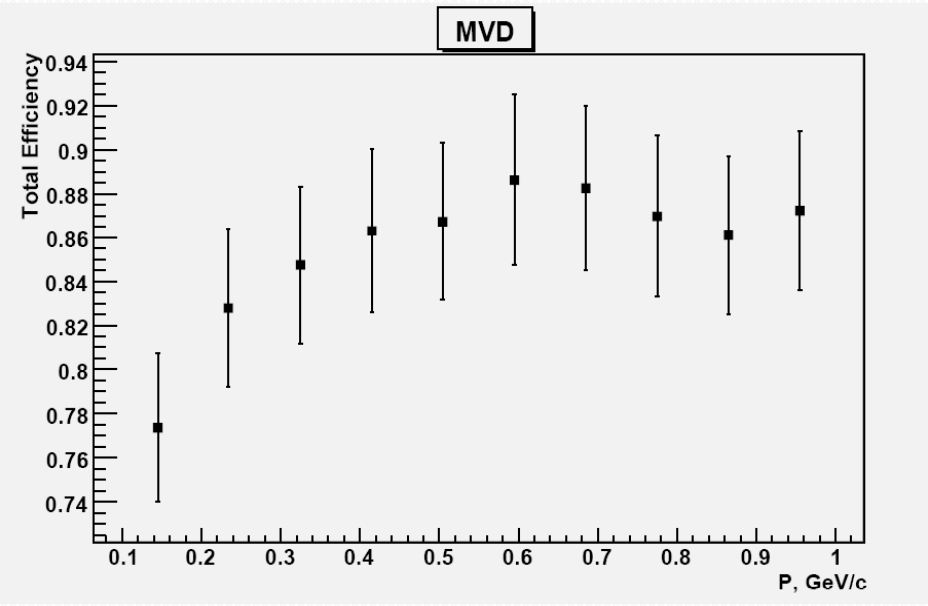
Ghosts = $\frac{\text{NumberOf"Ghosts"Tracks}}{\text{NumberOfRecoTracksWhichHaveAtLeast4Hits}}$

Gh=1/2=50%

1 Event = 6 Pions+ with random P and Theta (start point (0,0,0))

Total Finding efficiency

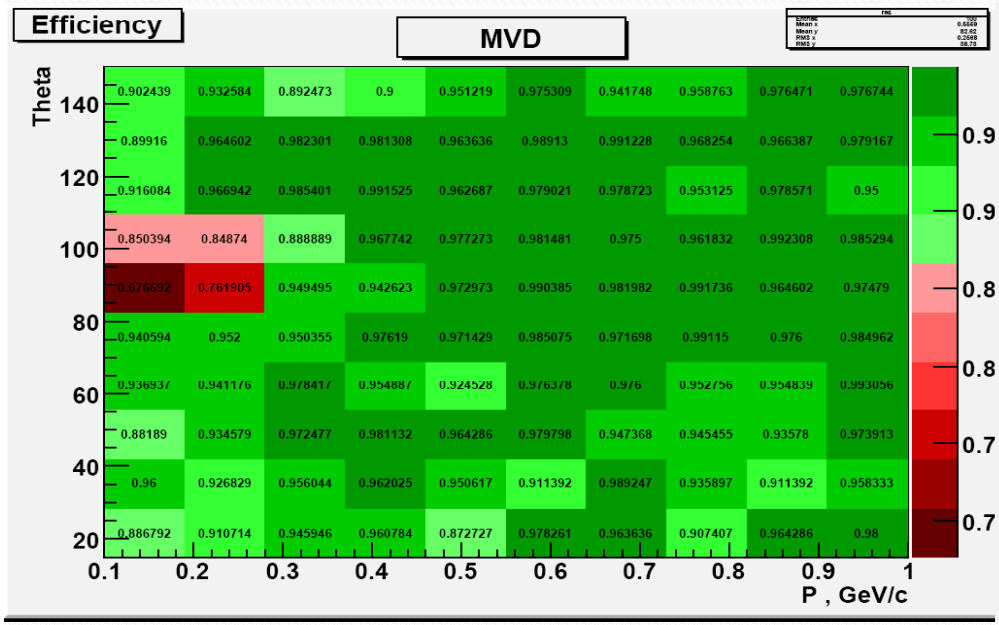


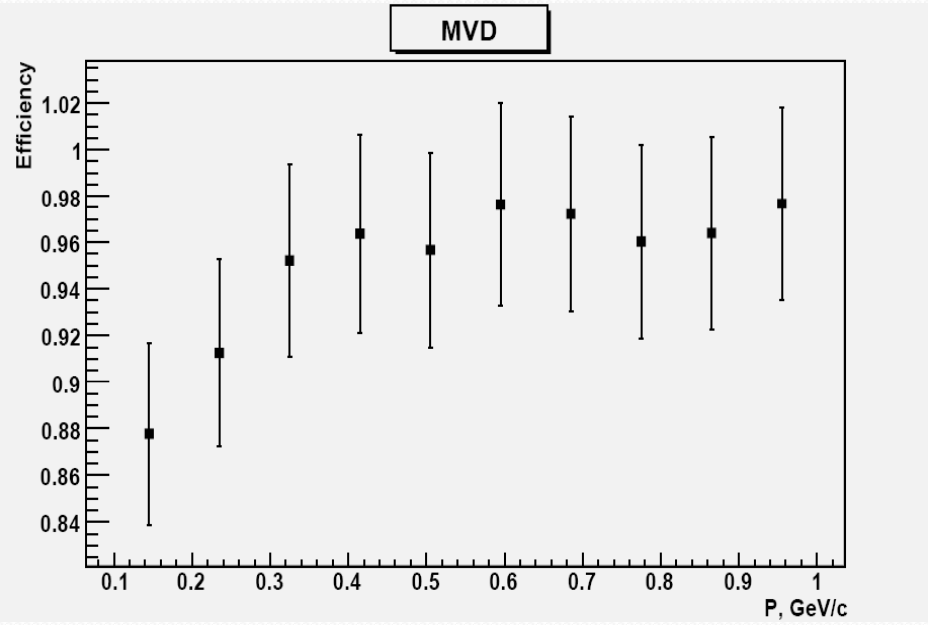


$$\text{Total finding efficiency} = \frac{\text{NumberOfTrueFoundTracks}}{\text{NumberOfMCTracks}}$$

1 Event = 6 Pions+ with random P and Theta (start point (0,0,0))

Finding efficiency

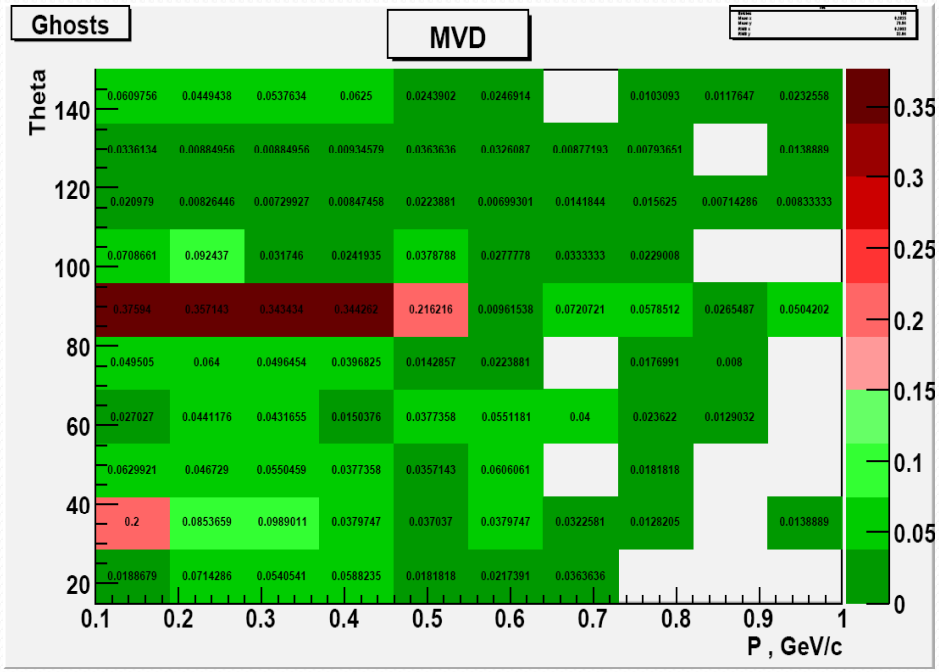


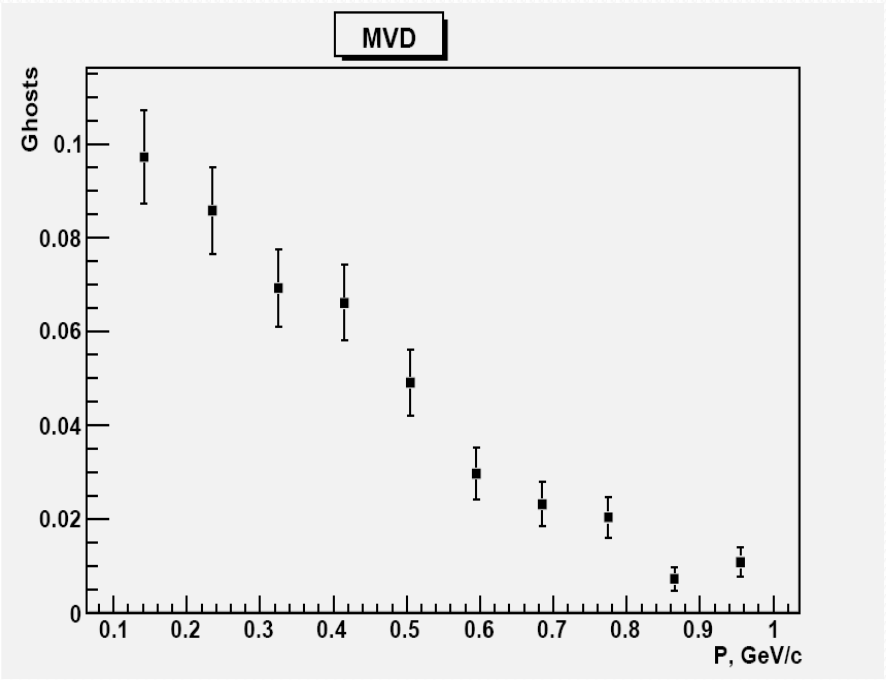


$$\text{Finding efficiency} = \frac{\text{NumberOfTrueFoundTracks}}{\text{NumberOfRecoTracksWhichHaveAtLeast4Hits}}$$

1 Event = 6 Pions+ with random P and Theta (start point (0,0,0))

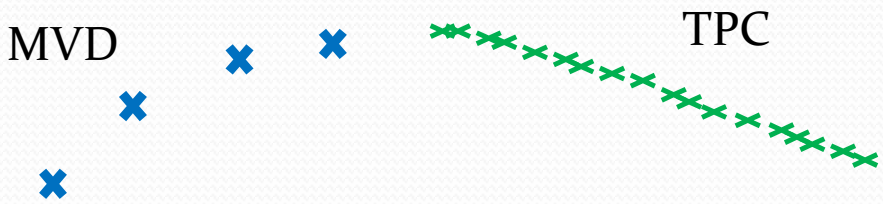
Ghosts





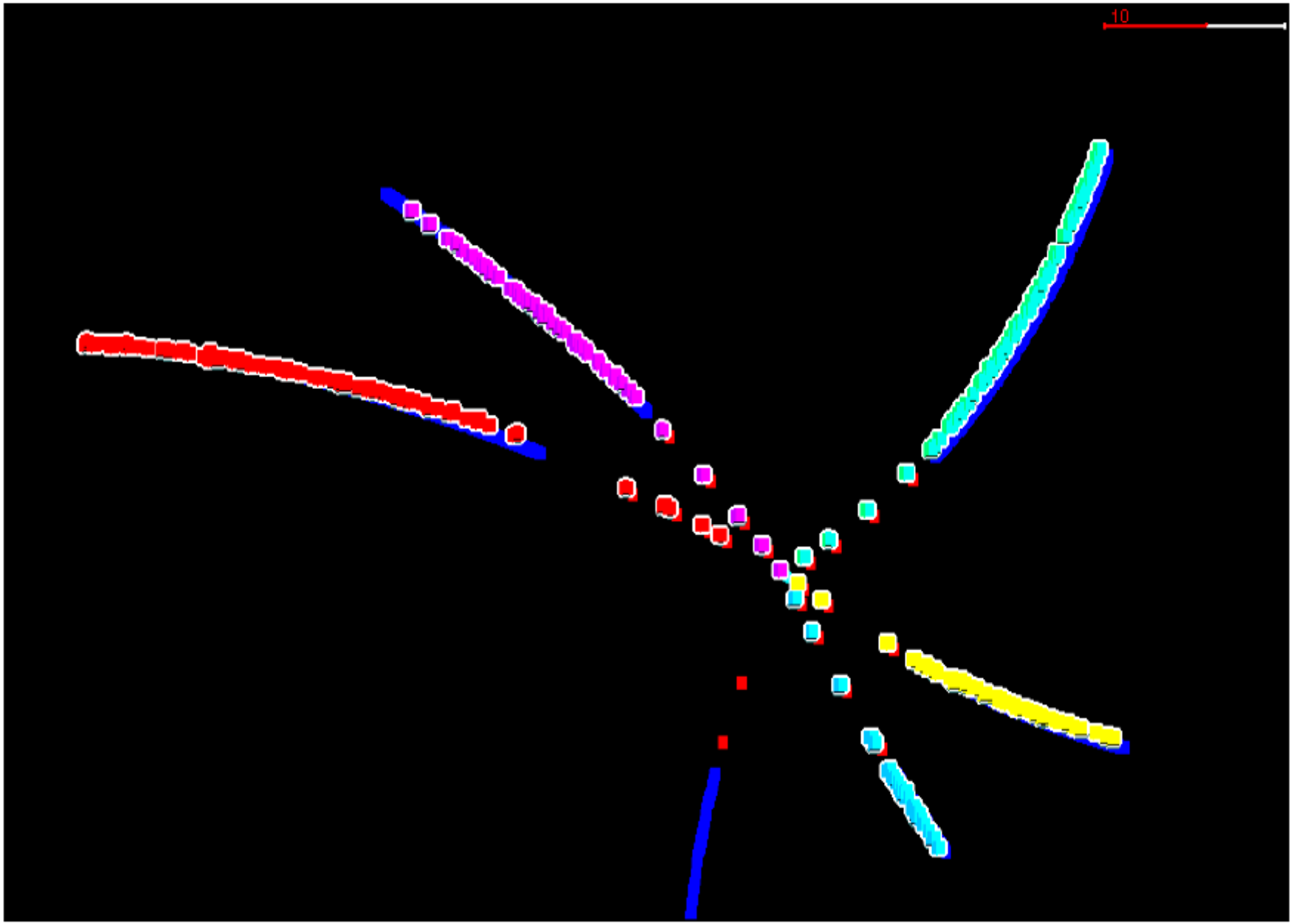
$$\textbf{Ghosts} = \frac{\text{NumberOf"Ghosts"Tracks}}{\text{NumberOfRecoTracksWhichHaveAtLeast}\mathbf{4}\text{Hits}}$$

Using the Riemann track finder for MVD + TPC



- For better speed of finding I take the found tracks of the MVD and just check the distance to the Riemann plane of these tracks and SZline-Chi2 for all TPC hits without refitting.

- But TPC hits need new cut parameters.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Finding efficiency for MVD+TPC

True Found track – has at least **4** identical MVD-hits + **4** TPC-hits with Reco track and all this MVD-hits belong to thw Reco track.

"**Ghost" tracks**– all other found tracks.

Blue – MVD-RECO-hits

Yellow – TPC-RECO-hits

Green – Hits of found track

$$\textbf{Total finding efficiency} = \frac{\text{NumberOfTrueFoundTracks}}{\text{NumberOfMCTracks}}$$

$$\textbf{Finding efficiency} = \frac{\text{NumberOfTrueFoundTracks}}{\text{NumberOfRecoTracksWhichHaveAtLeast4MVD\&4TPC-Hits}}$$

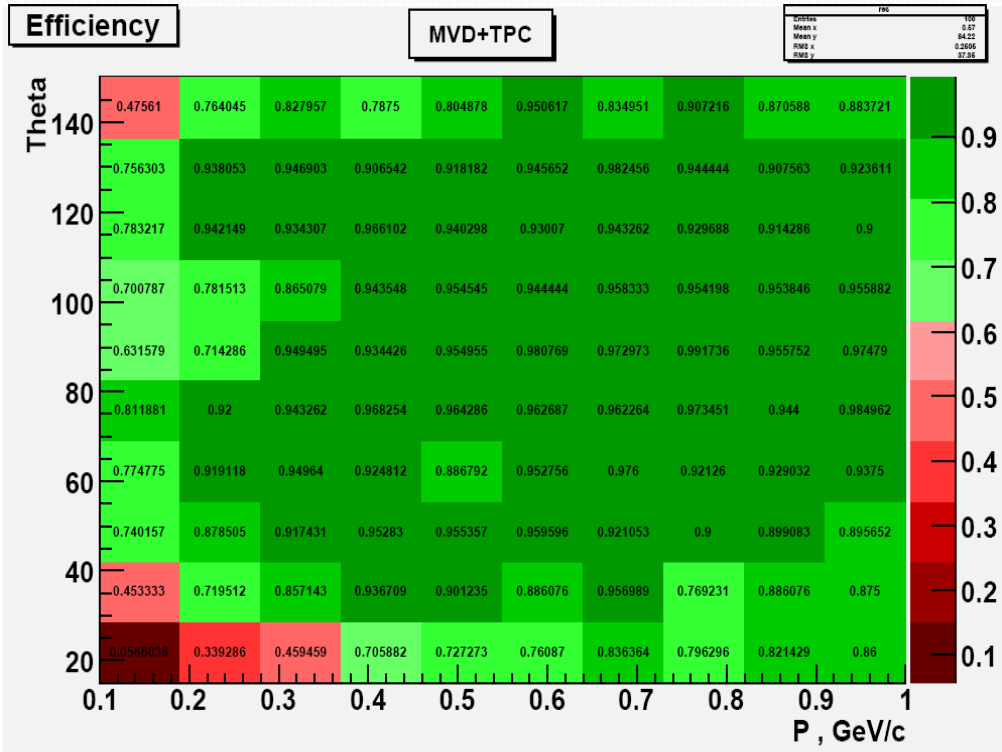
$$\textbf{Ghosts} = \frac{\text{NumberOf"Ghosts"Tracks}}{\text{NumberOfRecoTracksWhichHaveAtLeast4MVDHits\&4TPC-Hits}}$$

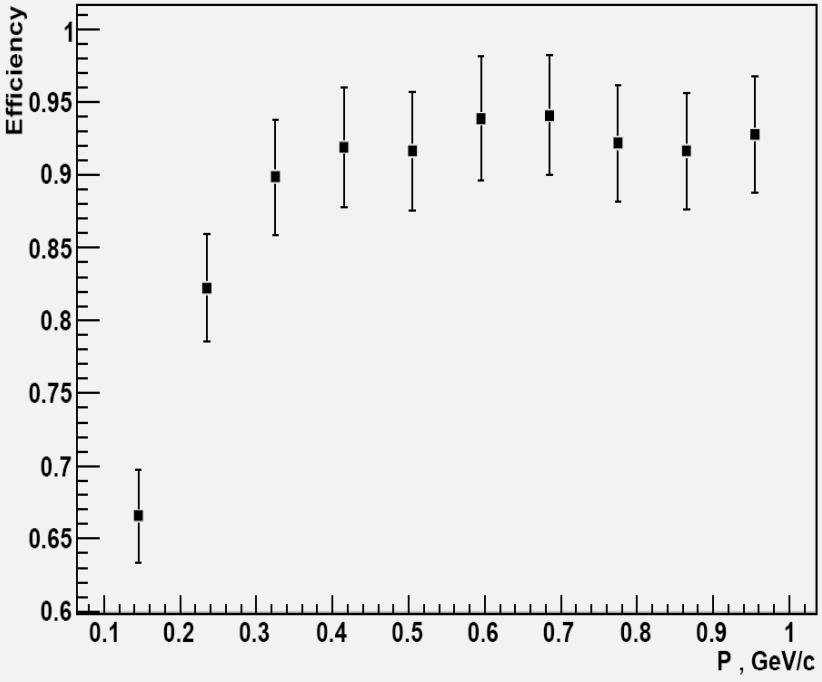
$$\textbf{TPC hits efficiency} = \frac{\text{NumberOfTrueTPCHitsInFoundTracks}}{\text{NumberOfTPCHitsInRecoTracks}}$$

$$\textbf{TPC hits ghosts} = \frac{\text{NumberOfFalseTPCHitsInFoundTracks}}{\text{NumberOfTPCHitsInRecoTracks}}$$

1 Event = 6 Pions+ with random P and Theta (start point (0,0,0))

Finding efficiency

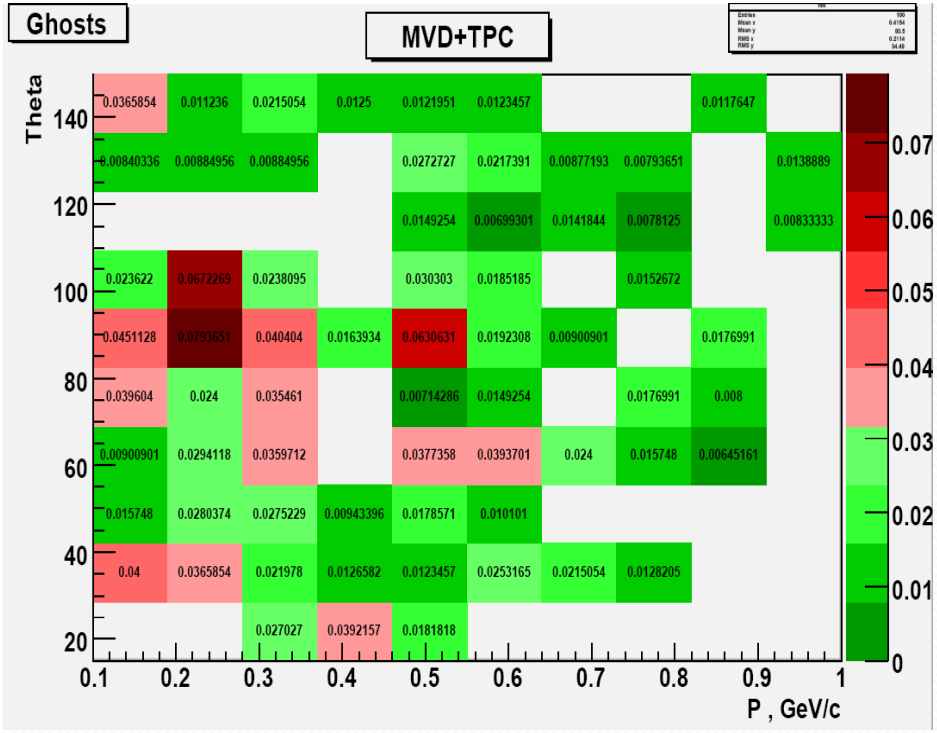


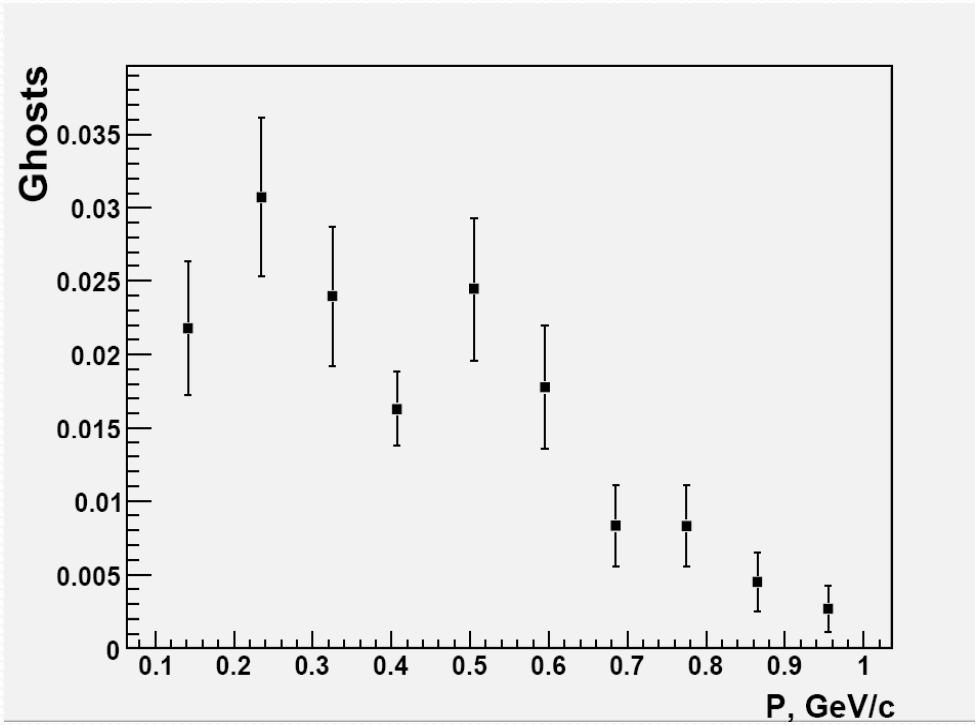


$$\text{Finding efficiency} = \frac{\text{NumberOfTrueFoundTracks}}{\text{NumberOfRecoTracksWhichHaveAtLeast4MVD\&4TPC-Hits}}$$

1 Event = 6 Pions+ with random P and Theta (start point (0,0,0))

Ghosts

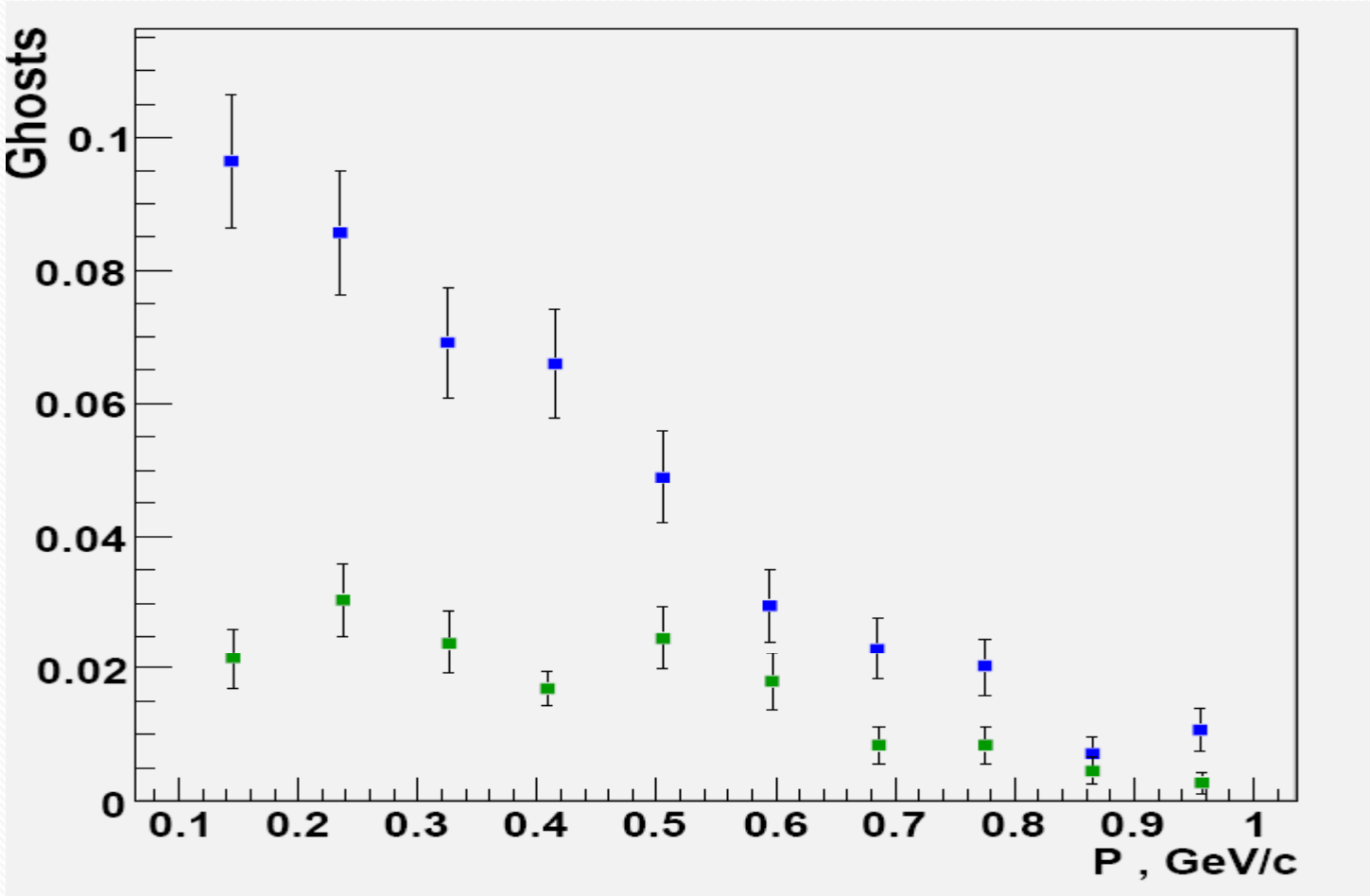




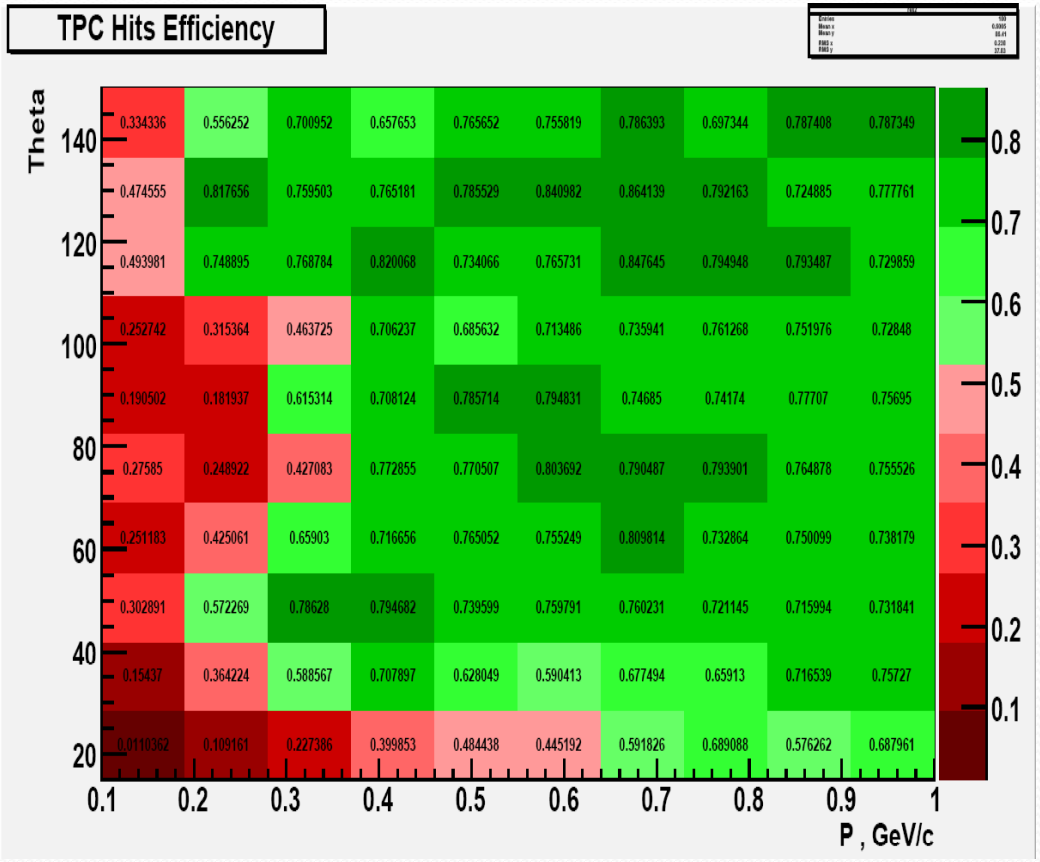
$$\textbf{Ghosts} = \frac{\text{NumberOf"Ghosts"Tracks}}{\text{NumberOfRecoTracksWhichHaveAtLeast}\mathbf{4}\text{MVDHits\&}\mathbf{4}\text{TPC-Hits}}$$

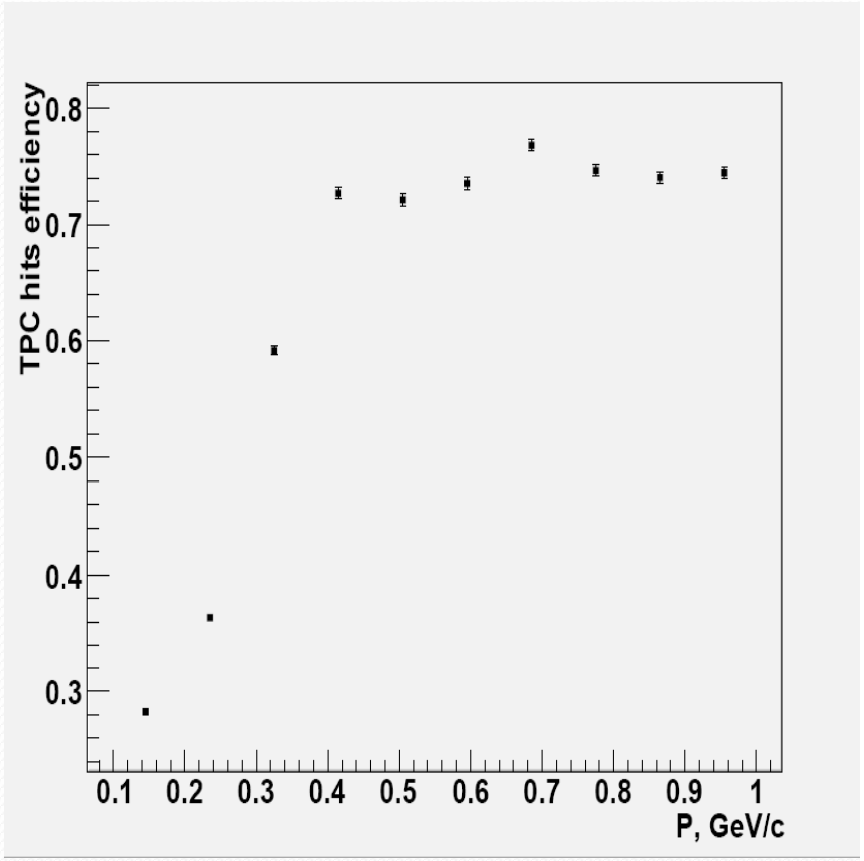
Comparison:

- Blue – MVD
- Green – MVD+TPC



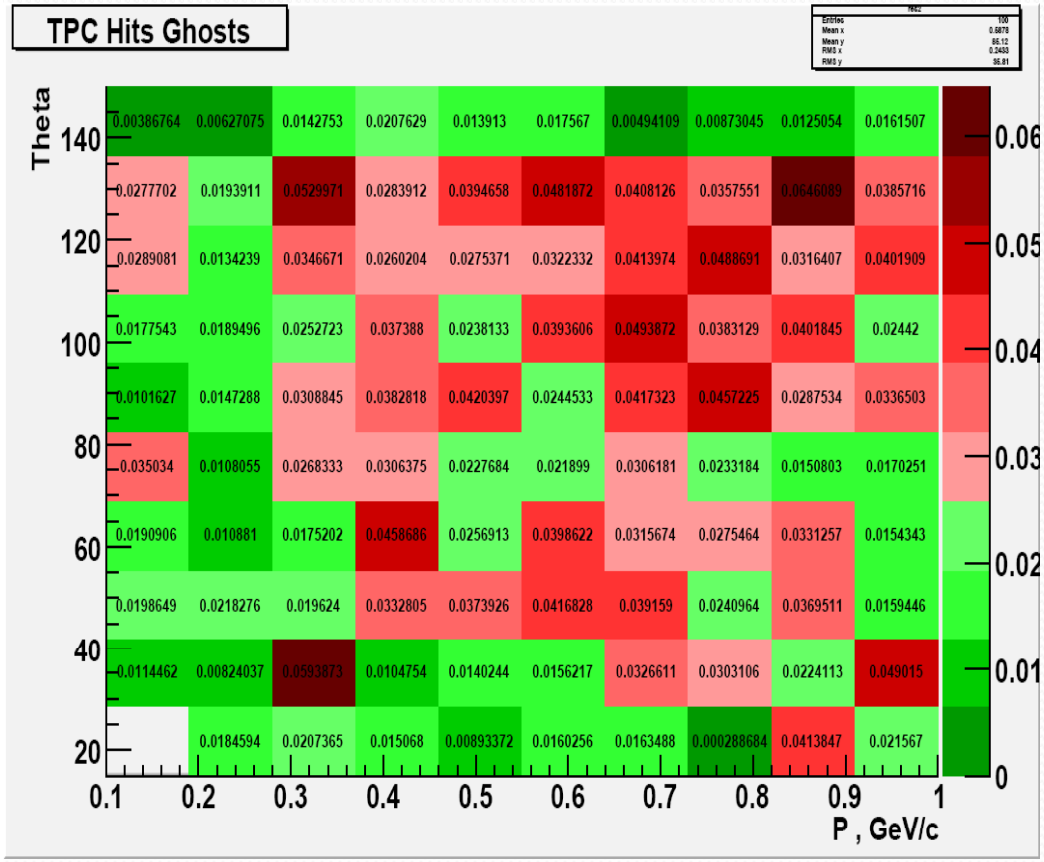
TPC Hits Efficiency

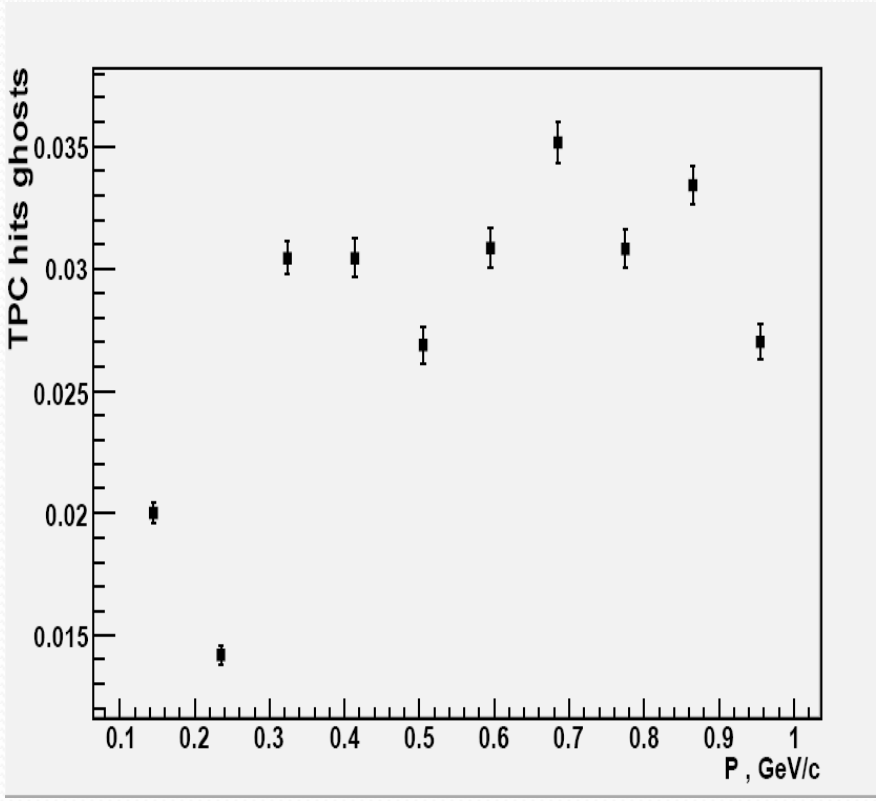




$$\textbf{TPC hits efficiency} = \frac{\text{NumberOfTrueTPCHitsInFoundTracks}}{\text{NumberOfTPCHitsInRecoTracks}}$$

TPC Hits Ghosts





$$\textbf{TPC hits efficiency} = \frac{\text{NumberOfFalseTPCHitsInFoundTracks}}{\text{NumberOfTPCHitsInRecoTracks}}$$

Summary

- Obtained Total Finding Efficiency and Finding Efficiency for **MVD**: TFE=85% , FE=95%, Ghosts=4.5%

- Obtained Total Finding Efficiency and Finding Efficiency for **MVD+TPC**: TFE=80% , FE=90%, Ghosts=1.5%

- Open questions:
  - **What to do with tracks that have less then 4 MVD- hits?**
  - **➔use TPC tracks as seed for MVD.**
  - **Using Riemann Track Finder as vertex finder/fitter.**

Thanks For Attention!

Addition

The fitted plane is defined by minimizing:

$$S = \sum_{i=1}^{N} \frac{(c + n_1 \cdot x_i + n_2 \cdot y_i + n_3 \cdot z_i)^2}{\sigma_i^2}$$

$\vec{n}$ - normal vector to the Riemann plane

C – distance to the Riemann plane from the origin

σ_i - measurement error in XY-plane

$\vec{n}$ - is chosen as the unit eigenvector corresponding to the smallest eigenvalue of the sample covariance matrix A of the measurements

$$\vec{A} = \frac{1}{N} \sum_{i=1}^{N} \frac{1}{\sigma_i^2} \cdot (\vec{r}_i - \vec{r}_{CG}) \cdot (\vec{r}_i - \vec{r}_{CG})^T$$

$\vec{r}_{CG}$ - centre of gravity

$$c = -\vec{n}^T \cdot \vec{r}_{CG}$$

$$w - 2 \cdot x_0 \cdot x - 2 \cdot y_0 \cdot y + {x_0}^2 + {y_0}^2 - R_0^2 = 0$$

$$c + n_1 \cdot x + n_2 \cdot y + n_3 \cdot w = 0$$

The centre and radius of the circle:

$$x_0 = -\frac{n_1}{2 \cdot n_3}$$

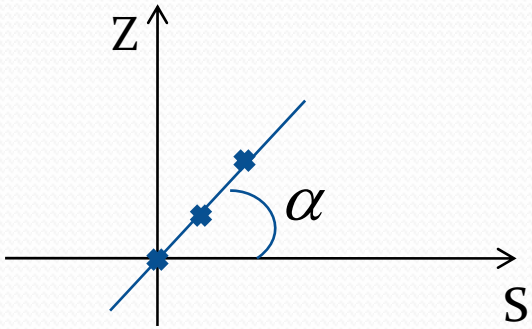
$$y_0 = -\frac{n_2}{2 \cdot n_3}$$

$$R_0 = \sqrt{\frac{1 - {n_3}^2 - 4 \cdot c \cdot n_3}{4 \cdot n_3^2}}$$

Connection between track's {radius - R, dip} and {Pt ,θ }

$$Pt = q \cdot R \cdot B$$

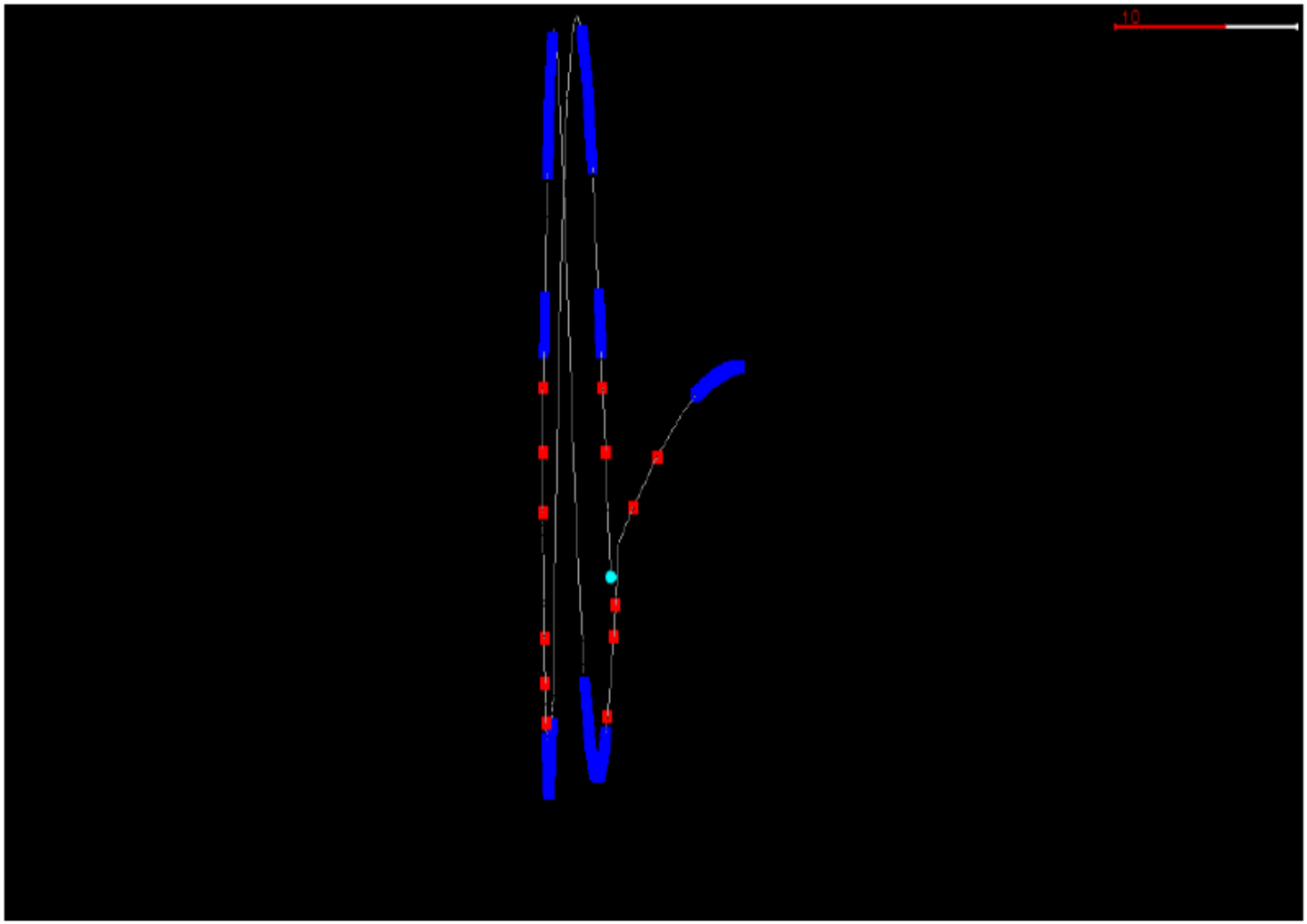
$$B = 2T$$



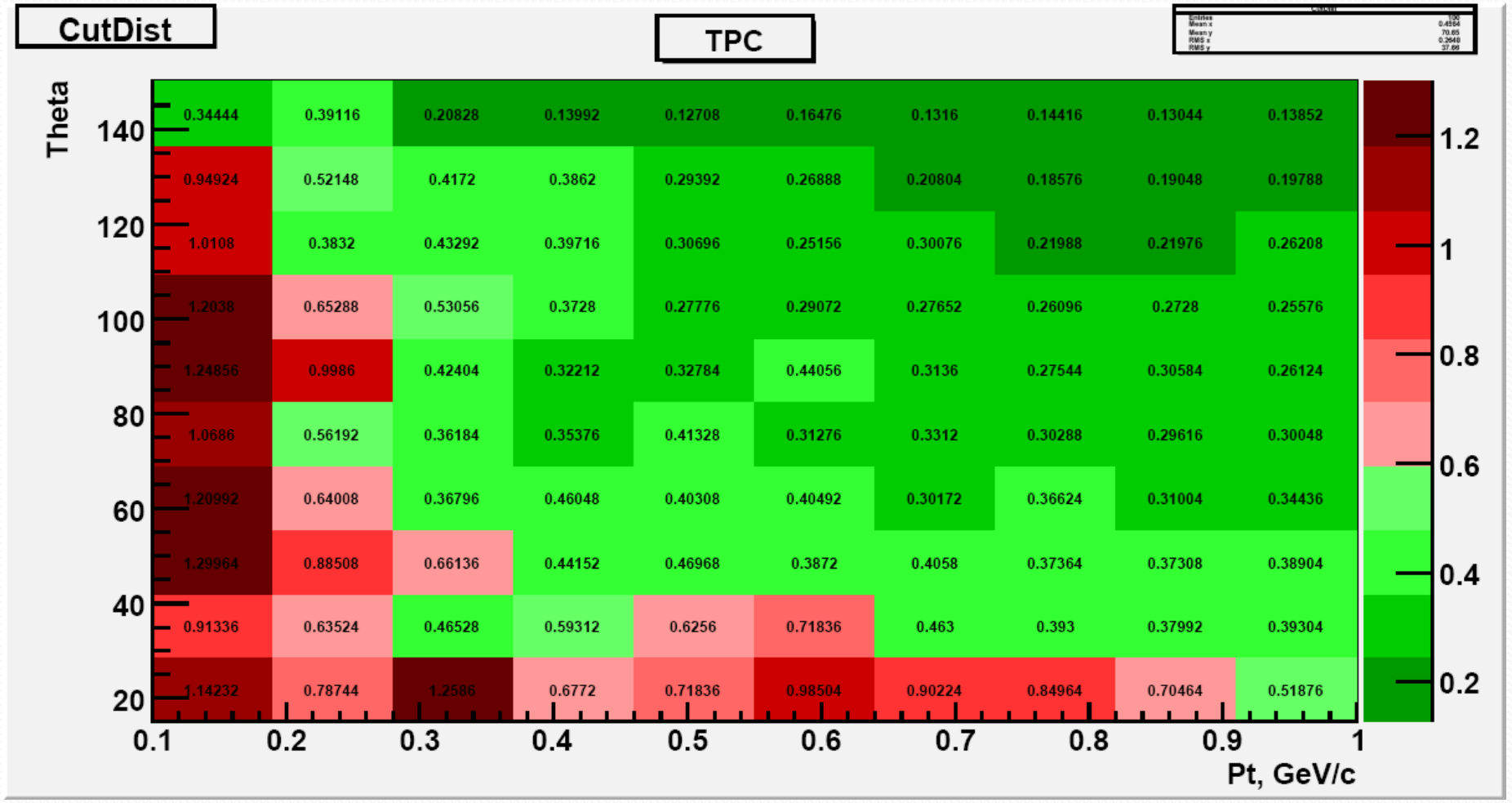
$$\theta = arctg\left[\frac{1}{|tg(\alpha)|}\right]$$ For forward tracks

$$\theta = \pi - arctg\left[\frac{1}{|tg(\alpha)|}\right]$$ For backward tracks

Pion+ : Px=-0.008604 GeV, Py=0.149243 GeV, Pz=-0.075131 GeV
P=0.167GeV



Cut distance for TPC hits



Cut SZline-Chi2 for TPC hits